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Optimisation of Decolourising Earth and Temperature use in the Decolourisation of Palm Oil

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Abstract – **The objective of this study was to optimise the use of decolourising earth and the temperature in the discolouration of crude palm oil (CPO). Three types of bleaching earth (American, Indian and Chinese) were characterised, while the effectiveness of each type was determined. A four factor composite experimental design was used to determine the different effects of the studied parameters on the colour response of bleached palm oil (BPO). The results showed that American earth was the most efficient. Its effect with a deterioration of bleach index (DOBI) oil of 2.3 showed that when the decolourising earth and the phosphoric acid were at their high level, the minimum values of the contour lines of the colour were 14.6, and when they were at their low level, these lines oscillated around 15.2. When the introduction temperature of phosphoric acid and decolourising earth were at their high level, the minimum values of the contour lines of the colour were 14.4 and when they were at their low level these lines oscillated around 15.4. The optimum discolouration conditions (≤ 20 red max) of CPO ($P \leq 0.05$) are : 100°C and 0.06% (mass) for the temperature and the percentage of phosphoric acid ; 116°C and 1.2% (mass) for the temperature and the percentage of the decolourising earth.**

Keywords – **Colour, Decolourising Earth, Experimental Design, Optimisation, Palm Oil, Temperature.**

I. Introduction

In recent years, global demand for palm oil has increased significantly, gaining market share at the expense of other, less accessible and more expensive vegetable oils, such as soybean oil. The superior demand for supply is likely to increase in the future, making it a very attractive product for investors [1]. According to Food and Agriculture Organisation (F.A.O.), palm oil production is estimated at 210,000 tons in 2010 and 322,000 tons in 2012, and Cameroon ranks the 4th producer in Africa after Nigeria (960000 tonnes) Ivory Coast (415000 tons) and the Democratic Republic of Congo (296,000 tons). Cameroon's production of palm oil currently stands at 225,000 tons in 2015 [2]. The production and refining of palm oil are highly profitable projects that favor the establishment of several transformer companies, and the demand for these booming industries outstrips supply. In Cameroon, crude red palm oil tends to compete with its refined oil due to the transformation of dietary patterns [3]. National demand for refined vegetable oils ranged between 140,000 and 150,000 tons compared to an offer valued at 70,000 tons [4]. The annual structural deficit in palm oil is 130,000 tons [5]. In order to fill the supply gap in refined oil and to cope with the import of these products, refined companies are always more competitive by offering quality products permanently. But, they face the instability of the color of the refined oil, causing their depreciation and reducing their market share.

Taking into account, on the one hand, the large number of parameters (crude oil quality and inputs such as bleaching earth and phosphoric acid) which can influence the colour of the bleached oil and on the other hand, the difficulty in assessing the relevance of each product to the problem of colour non-conformity, the literature and the information collected from refining operators have made it possible to lay emphasis on discolouring earth and temperature. Thus, the aim of this work is to optimise the use of the decolourising earth and the temperature in the discoloration of the crude palm oil.

II. Material and Methods

A. Biological Material

The biological material was crude palm oil (CPO) and bleached palm oil (BPO) gracefully from the AZUR S.A. plant located in the Yassa quarter (Douala, Cameroon).

B. Methods

B.1. Evaluation of the Performance of Decolourising Earth used

The characterisation of the decolourising earth used (AZUR S.A.) was carried out by determining their water content, pH and acidity. The performance of the decolourising earth was evaluated by determining the deterioration of bleach index (DOBI) of the crude palm oil and the colour of BPO. The sampled masses were determined by the use of a precision (0.001) balance (*KERN*).

B.1.1. Determination of Moisture Content of Decolourising Earth

The moisture content of decolourising earth was determined by the use of a moisture meter marked *RADWAG*. Its principle consists in the determination of the water content in the samples, eliminated by evaporation at an average temperature of 100°C. After having tared it, 2g of earth is weighed and the results in percentage can be read on the display screen.

B.1.2. Determination of the Acidity of the Decolourising Earth

Acidity is the percentage of acid in a solution or compound. In the case of decolourising earth, the percentage of acid, expressed as a percentage of sulphuric acid is determined. The NF method [6] was used for this purpose.

B.1.3. Determination of pH

A digital pH-meter (pH *212 HANNA*) equipped with two combined electrodes was used to determine the pH.

B.1.4. Determination of the DOBI of Crude Palm Oil

The DOBI is numerically the ratio of the spectrophotometric absorbance at 446 nm of palm oil to the absorbance at 269 nm of the same palm oil. The determination of DOBI, which is an indication of the degradation state of the crude palm oil, helped to have insights of the quality of the oil before treatment and its state of oxidative degradation. The analysis of DOBI values was carried out by the use of spectrophotometer (*Pharmaspec*, UV-1700 Model). It consists in absorbing the intensity of the carotenoids and the oxidation products respectively at a wavelength 446 and 269 nm.

B.1.5. Bleaching

Bleaching helps to absorb the undesirable compounds contained in the crude oil (primary and secondary oxidation products, metals, soaps, phosphate compounds) [7, 8]. The samples were heated using a heating plate (*ELTAC*). A thermometer with a maximum temperature of 250°C was used to control the temperature during bleaching.

The principle is based on the fixing of phosphatides from phosphoric acid and their precipitation by dosing the decolourising earth followed by filtration. It helps to filter the oil of its impurities and prepares deodorisation. In addition, the success of bleaching depends on the colour of refined bleached and deodorised palm oil (RBD). Table 1 presents the characteristics of inputs for bleaching.

Table 1. Characteristics of inputs for bleaching

Inputs	Mass (g)	DOBI	FFA	Temperature (°C)	Percentage (%)
CPO	50	2.3	5.2		
H_3PO_4				100	0.05
Decolourising earth				120	1.2

CPO: Crude Palm Oil; FFA: Free fatty Acids

B.1.6. Determination of the Colour of Bleached and Deodorised Oil

Colour is the sensation produced on the eye by the radiation of light as absorbed or reflected by bodies. A tintometer (*Lovibond Tintometer* 180000 *Model F*) was used to determine the colour of the BPO samples. The determination of BPO by the tintometer is based on the variation of the red, yellow and blue colour, the function of coloured constituents of the sample and the quality of the refining. The standards for AZUR S.A are presented in table 2.

Table 2. Standard of refined oil in AZUR S.A.

Products	Standards
BPO	20 red max
RBD	3 red max
Oléine	4 red max

BPO: Bleached Palm Oil; RBD: Refined Bleached Deodorised oil

B.2. Optimisation of use of Decolourising Earth and Temperature

B.2.1. Choice of Factors and Experimental Domain

The colour of the palm oil can be improved by means of an experimental design. The four-factor composite experimental design was used for this purpose. This experimental design method was used because the industrial results showed that the response (colour of the bleached palm oil) was not linearly dependent on the study factors shown in table 3. Surface curvature of response is taken into account through the quadratic effect of each of the variables and their interactions. In order to compare the effect of each factor on the response, these factors U_i must be coded as reduced variables xi (table 3). The variation domain of each factor ranges from the lowest value to the highest with a variation step that facilitates a regular growth or decay from one level of variable to another according to equation (1) [9] :

$$U_i = U_0 + \Delta U \times x_i \quad (1)$$

U_i is the value of the natural variable i (real value); x_i is the value of the coded variable i, U_o is the value of the centre of the variation domain of the factor (equation 2). And ΔU is the variation step.

$$U_0 = \frac{U_{max} + U_{min}}{2} \quad (2)$$

The absolute value α of the boundaries of the domain of variation of each factor is given by the relation 3 in which n is the number of factors.

$$\alpha = (2^n)^{0.25},\ n = 4 \text{ and } \alpha = 2 \quad (3)$$

Bleaching temperatures (in °C), percentage of phosphoric acid (in %) and percentages of decolourising earth (in %) were used to determine the different colour responses. Scientific papers and ranges used in the company helped to confirm the choice of factors (table 3).

Table 3. Factors, domains of variation and centre of the domain

Real variables		Coded variables					
		-α	-1	0	+1	+α	ΔXi
Introduction temperature of phosphoric acid (°C)	x_1	85	90	95	100	105	10
% phosphoric acid	x_2	0.03	0.05	0.065	0.08	0.1	0.02
Introduction	x_3	105	110	115	120	125	10

Real variables		Coded variables					
		-α	-1	0	+1	+α	ΔXi
temperature of decolourising earth (°C)							
% decolourising earth	x_4	0.6	0.8	1	1.2	1.4	0.4
Red colour response	Y_i						

For an n factor experimental design, the number of experiments is given by the relation 4:

$$N = 2^n + 2n + C \qquad (4)$$

Number of tests required $2^n = 16$; Number of star points $2n = 8$; Number of tests at centre $C \geq 4$.

Therefore N = 28 experiments minimum.

B.2.2. Matrix of Experiments and Second Order Polynomial Model

The organisation of the experiments is presented in table 4 which includes the matrix of experiments in reduced variables, the matrix of the corresponding tests and the values of the responses obtained. The advantage of the experimental design is that the experiments to be carried out are predetermined and can be carried out in any order.

Table 4. Matrix of composite plan experiments (American decolourising earth)

	Coded values				Real values				Responses
N°	X_1	X_2	X_3	X_4	U_1	U_2	U_3	U_4	Y
1	**0**	**0**	**0**	**0**	95	0.06	115	1.2	15.5
2	**-1**	**-1**	**-1**	**-1**	90	0.05	110	0.8	15.4
3	**1**	**-1**	**-1**	**-1**	100	0.05	110	0.8	14.5
4	**-1**	**1**	**-1**	**-1**	90	0.08	110	0.8	14.8
5	**1**	**1**	**-1**	**-1**	100	0.08	110	0.8	14.1
6	**-1**	**-1**	**1**	**-1**	90	0.05	120	0.8	14.1
7	**1**	**-1**	**1**	**-1**	100	0.05	120	0.8	14.7
8	**-1**	**1**	**1**	**-1**	90	0.08	120	0.8	14.5
9	**1**	**1**	**1**	**-1**	100	0.08	120	0.8	14.2
10	**0**	**0**	**0**	**0**	95	0.06	115	1.2	15.5
11	**-1**	**-1**	**-1**	**1**	90	0.05	110	1.2	14.6
12	**1**	**-1**	**-1**	**1**	100	0.05	110	1.2	13.4
13	**-1**	**1**	**-1**	**1**	90	0.08	110	1.2	14.8
14	**1**	**1**	**-1**	**1**	100	0.08	110	1.2	14
15	**-1**	**-1**	**1**	**1**	90	0.05	120	1.2	15
16	**1**	**-1**	**1**	**1**	100	0.05	120	1.2	14
17	**-1**	**1**	**1**	**1**	90	0.08	120	1.2	13.8
18	**1**	**1**	**1**	**1**	100	0.08	120	1.2	13
19	**0**	**0**	**0**	**0**	95	0.06	115	1.2	16.1
20	**-α**	**0**	**0**	**0**	**85**	0.06	115	1.2	16.5
21	**+α**	**0**	**0**	**0**	**105**	0.06	115	1.2	15.5
22	**0**	**- α**	**0**	**0**	95	**0.03**	115	1.2	15.2
23	**0**	**+α**	**0**	**0**	95	**0.1**	115	1.2	14.7
24	**0**	**0**	**- α**	**0**	95	0.06	**105**	1.2	16
25	**0**	**0**	**+α**	**0**	95	0.06	**125**	1.2	14.5
26	**0**	**0**	**0**	**- α**	95	0.06	115	**0.6**	16.4
27	**0**	**0**	**0**	**+α**	95	0.06	115	**1.4**	15.1
28	**0**	**0**	**0**	**0**	95	0.06	115	1.2	16.5

The polynomial model of degree 2 postulated (equation 5) for four variables is of the following form:

$$Y_i = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_{ij} x_i x_j \qquad (5)$$

Where Yi is the desired response (bleached palm oil colour), β0 the constant, βi the linear coefficients x_i, βii the coefficients of the square terms x_i^2, βij the coefficients of the interaction terms $x_i x_j$.

These coefficients must be calculated using equation 6 below.

$$\beta_i = (X'X)^{-1} X'Y \qquad (6)$$

Where X is the matrix of the model, X' is the transpose of X, (X' X) the information matrix, $(X' X)^{-1}$ the dispersion matrix and Y the vector of the experimental responses.

B.2.3. Estimation the Weight of Each Factor and their Interactions on the Response

The analysis of Pareto [10] helps to estimate the weight of each factor and their interactions on the response according to relation 7 below:

$$F_i = 100 \frac{\beta_i^2}{\sum \beta_i^2} \qquad (7)$$

Where F_i is the percentage of the effect of variable i on the response, β_i^2 is the square of the estimated coefficient of variable i, $\sum \beta_i^2$ is the sum of the squares of the estimated coefficients of all variables.

B.2.4. Validation of Models

The coefficient of determination (R^2) and the Absolute Analysis of the Average Deviation (AADM) will help to validate the model. The coefficient R^2 must be equal to or greater than 0.95 and the AADM must be equal to 0 [11].

$$AADM = \sum_{i=1}^{P} \frac{\left(\left| \frac{\text{Yiexp - Yical}}{\text{Yiexp}} \right| \right)}{P}$$

With Y_{iexp} the experimental response and Y_{ical} the response calculated from the model for an experiment i; p being the total number of experiments.

B.3. Data Analysis and Processing

The experiments were carried out in triplicate. The SPSS (Statical Package Social Sciences version 2.0), Stat graphics version 2.0 and Sigma plot (version 12 build 12.0.0.77) [12, 13, 14] were used to express the results of the experiment matrix (fit line, diagram of effects, coefficients and equations of the model, curves of isoresponses).

III. Results and Discussion

A. Evaluation of the Performance of the Decolourising Earths used

A.1. Characterisation of Decolourising Earths

Table 5 presents the chemical characteristics of the decolourising earths. The moisture values decrease from earth 1 to earth 3, but the pH is in the opposite direction decreases from earth 3 to earth 1. As for the percentage of acidity, that of the earth 3 corresponds to 0.16, earth 2 to 0.11 and earth 3 to 0.29. It is observed that each decolourising earth differs significantly from the other two, depending on the characteristics compared: pH, acidity and moisture. This variation may be due to the origin and initial characteristics of the different types of earth.

Table 5. Characterisation of the various decolourising earths used

Parameters	Earth 1	Earth 2	Earth 3	Standard
Moisture (g of water/100g dry matter)	11.76 ± 0.06[a]	9.57 ± 0.24[b]	7.79 ± 0.02[c]	11% max
pH	7.22 ± 0.02[a]	8.12 ± 0.02[b]	8.81 ± 0.05[b]	6.5 ± 1.0
Acidity	0.29 ± 0.01[a]	0.12 ± 0.01[c]	0.17 ± 0.01[b]	0.3% max H_2SO_4

Means within rows with the same letter are not significantly different ($p < 0.05$)
Earth 1 = American; Earth 2 = Indian; Earth 3 = Chinese

A.2. Effectiveness of Decolourising Earth

Table 6 shows the efficiency of decolourising earth. After bleaching, a maximum colour of 16.7 is obtained with Chinese earth and a minimum colour of 15.1 with American earth. The American earth is therefore the one that gives a better colour because the desired character is the decrease of the colour and the norm is 20 red max.

The effectiveness of American earth could be explained by its more favourable characteristics. Indeed, the acidification of decolourising earth with a solution of mineral acid (H_2SO_4) increases the bleaching yield. According to [15], the acid treatment of bentonite neutralises part of the negative charge of the surface of the clay which becomes positively charged and makes the degumming easier to the reaction with the negatively charged ions (phosphatides). Moreover, when the moisture is at an optimum value, it ensures the absorption of water at the level of the structure of the molecule. This absorption takes place between the sheets which move away from one another. As for pH, it plays an important role in the mechanism of retention or release of gums. Indeed, the P-Fe, P-Ca, P-Al connections depend on the pH, its increase decreases the ability to fix Fe^{3+} or Al^{3+} of the clay due to the competition of OH^- and PO_4^- ions.

The American decolourising earth being the most effective, it will be used for the optimisation of the bleaching.

Table 6. Effectiveness of decolourising earths

Types of decolourising earth	Red colour of BPO
Earth 1	15.13±0.15[a]
Earth 2	15.78±0.49[b]
Earth 3	16.73±0.40[c]

Means within columns with the same letter are not significantly different ($p < 0.05$)
Earth 1 = American; Earth 2 = Indian; Earth 3 = Chinese

B. Modelling of Decolourising Earth and Temperature use

B.1. Results of the Experiment Design

The test matrix, obtained from the experimental matrix using American decolourising earth and DOBI 2.3 palm oil, gives the response values for all combinations (table 7).

Table 7. Test matrix with American decolourising earth

Experimental design						
N°	X_1 (°C)	X_2 (%H_3PO_4)	X_3 (°C)	X_4 (%Earth)	Experimental Y	Theoretical Y
1	95	0.06	115	95	15.5	15.9
2	90	0.05	110	90	15.4	15.4
3	100	0.05	110	100	14.5	14.7
4	90	0.08	110	90	14.8	15.4
5	100	0.08	110	100	14.1	14.8
6	90	0.05	120	90	14.1	14.9
7	100	0.05	120	100	14.7	14.7
8	90	0.08	120	90	14.5	14.4
9	100	0.08	120	100	14.2	14.3
10	95	0.06	115	95	15.5	15.9
11	90	0.05	110	90	14.6	15.2
12	100	0.05	110	100	13.4	14.0
13	90	0.08	110	90	14.8	15
14	100	0.08	110	100	14	14
15	90	0.05	120	90	15	14.8
16	100	0.05	120	100	14	14.1
17	90	0.08	120	90	13,8	14.1
18	100	0.08	120	100	13	13.6
19	95	0.06	115	95	16.1	15.9
20	85	0.06	115	85	16.5	15.7
21	105	0.06	115	105	15.5	14.5
22	95	0.03	115	95	15.2	14.4
23	95	0.1	115	95	14.7	13.8
24	95	0.06	105	95	16	14.8
25	95	0.06	125	95	14.5	14.02
26	95	0.06	115	95	16.4	15.3
27	95	0.06	115	95	15.1	14.3
28	95	0.06	115	95	16.5	15.9

X_1: Introduction temperature of phosphoric acid ; X_2 : Percentage of phosphoric acid ; X_3 : Introduction temperature of decolourising earth ; X_4 : Percentage of decolourising earth

The calculation of the coefficients of the model from the relation 6 using Stat graphic software enables us to write the mathematical model of the decolouration of crude palm oil as presented in equation 8_1:

$$Colour = 15.925 - 0.3125X_1 - 0.1375X_2 - 0.204167X_3 - 0.245833X_4 - 0.198958X_1X_1 + 0.04375X_1X_2 + 0.11875X_1X_3 - 0.10625X_1X_4 - 0.448958X_2X_2 - 0.11875X_2X_3 - 0.04375X_2X_4 - 0.373958X_3X_3 + 0.03125X_3X_4 - 0.261458X_4X_4 \quad (8_1)$$

B.1.1. Mathematical Analysis of the Results

It is observed from the signs of the coefficients of the model (table 8) that three interactions namely (introduction temperature phosphoric acid /introduction temperature of decolourising earth; AC), (introduction temperature of phosphoric acid/percentage of phosphoric acid; AB), (introduction temperature of decolourising earth/percentage of decolourising earth; CD), with respectively as coefficients 0.11875, 0.04375 and 0.03125 contribute to increase the colour of bleached palm oil instead of decreasing it. All other coefficients with negative signs contribute to the reduction in the colour of the bleached palm oil. The most significant terms in the discolouration of palm oil in the decreasing order are : BB : 28.29% (quadratic term ; percentage of phosphoric acid), CC : 19.63% (quadratic term; introduction temperature of decolourising earth), X_1 : 13.70% (introduction temperature of phosphoric acid), DD : 9.6% (quadratic term; percentage of decolourising earth) and X_4 : 8.5% (percentage of decolourising earth). These five terms contribute 79.72% to the discolouration of palm oil. BD, AB and CD interactions with non-significant response weight (0.27%: 0.27%, 0.14% respectively) should be removed from the model equation.

Table 8. Factor coefficient and weight on response

Factors	Coefficient	Coefficient square	% Effect
Constant	15.925		
BB	-0.448958	0.201563	28.29
CC	**-0.373958**	**0.139846**	**19.63**
$X_1 : T_1$	-0.3125	0.097656	13.70
DD	-0.261458	0.06836	9.6
X_4 : decolourising earth	-0.245833	0.060434	8.5
$X_3 : T_2$	-0.204167	0.0416841	5.85
AA	**-0.198958**	**0.0395843**	**5.56**
$X_2 : H_3PO_4$	-0.1375	0.018906	2.65
BC	**-0.11875**	**0.0141015**	**1.98**
AC	0.11875	0.0141015	**1.98**
AD	-0.10625	0.0112890	1.58
BD	-0.04375	0.001914	0.27
AB	0.04375	0.001914	0.27
CD	0.03125	0.0009765	0.14
		$\sum \beta_i^2 =$ 0.7123299	

The reduced model equation (relation 8_2), after elimination of non-influencing factors is as follows:

$$Colour = 15.925 - 0.3125X_1 - 0.1375X_2 - 0.204167X_3 - 0.245833X_4 - 0.198958X_1X_1 + 0.11875X_1X_3 - 0.10625X_1X_4 - 0.448958X_2X_2 - 0.11875X_2X_3 - 0.373958X_3X_3 - 0.261458X_4X_4 \quad (8_2)$$

The resolution of this equation helps to obtain the optima in coded and real values (table 9)

Table 9. Optima in coded and real values of equation (8_2)

Factors	X_1	X_2	X_3	X_4
Coded values	0.98	0.12	-0.107	0.68
Real values	100°C	0.06%	116°C	1.2%

X_1: Introduction temperature of phosphoric acid; X_2: Percentage of phosphoric acid; X_3: Introduction temperature of decolourising earth; X_4: Percentage of decolourising earth

B.1.2. Validation of the Model

The statistical analysis shows that the proposed models are valid with satisfactory values of R^2 and AADM. The coefficient of the regression line is 0.98. In addition, the AADM value tends to 0 (table 10).

Table 10. Validation of the discolouration model

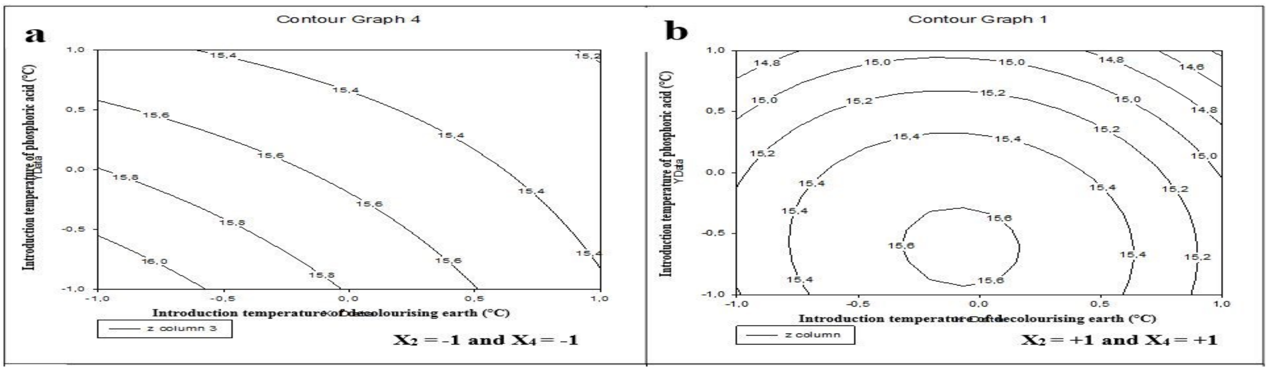
Validation element	Abbreviation	Value obtained	Standard value
Coefficient of determination	R^2	0.984	100%
Absolute analysis average deviation	AADM	0.0001029	0

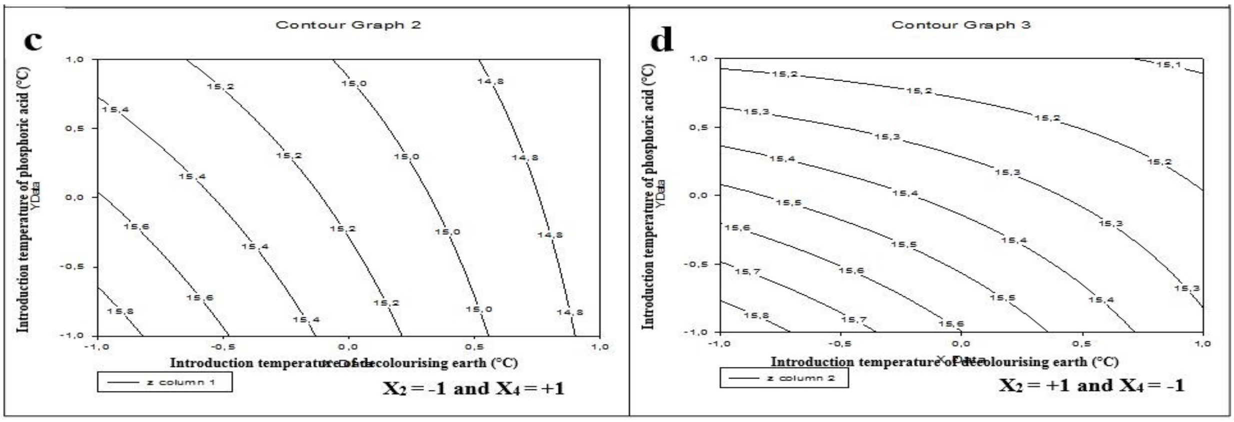
Based on the results in table 10, we assume that the experimental results do not contain an error and even if there was an error, it would be constant and independent of the variation of the factors involved in this study.

B.2. Optimisation of Discolouration

B.2.1. Influence of Decolourising Earth and Acid Levels on BPO Colour

The curves in fig.1 (a, b, c, and d) shows the isoresponse curves of the change in colour response when the decolourising earth and phosphoric acid are at their high level (1) and low level (-1). When the decolourising earth and the phosphoric acid are at their high level the minimum values of the contour lines of the colour are at 14.4 and when they are at their low level, these lines oscillate around 15.2. These contour lines show that the colour varies according to the proportion of decolourising earth and phosphoric acid. This could be explained by the fact that the high level of phosphoric acid contributes to the fixation of all the gums susceptible to be found in the crude palm oil and high level of the earth fixes all these precipitated gums. Curves 1c and 1d indicate that the level of the earth influences the behaviour of the response.





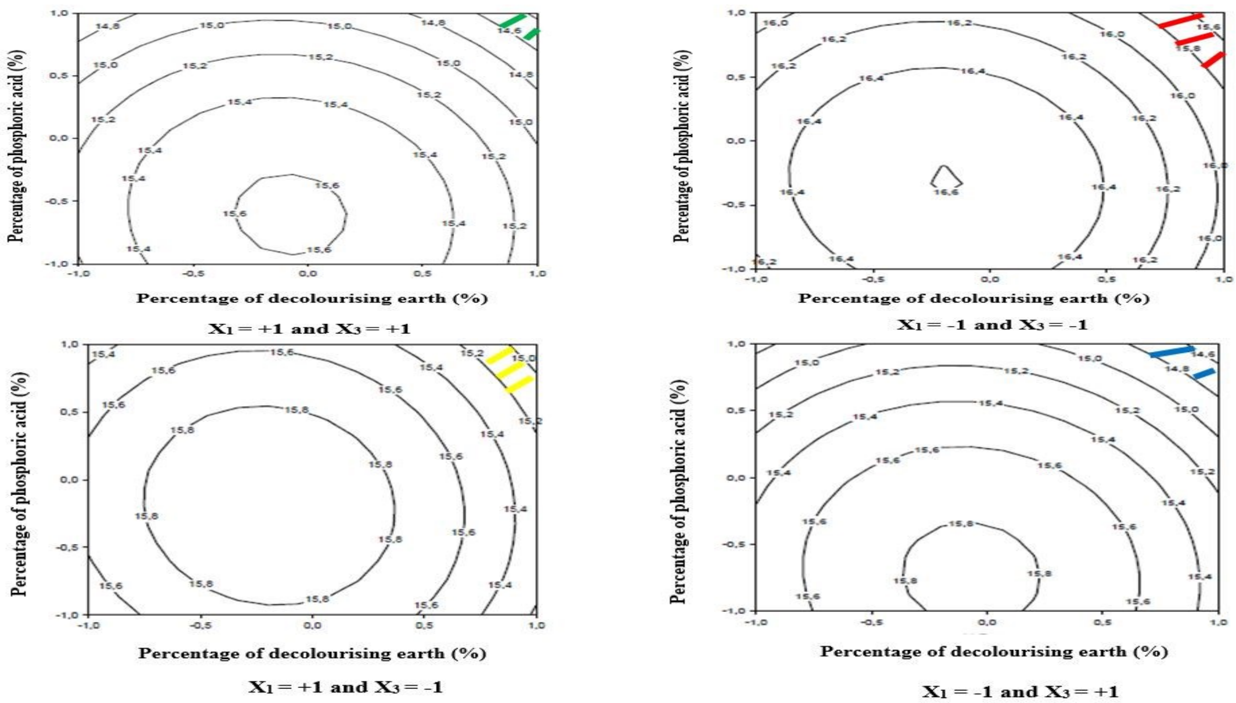
X_2: Percentage of phosphoric acid (%); X_4: Percentage of decolourising earth (%)

Fig.1. Isoresponses curves of the colour as a function of the levels of decolourising earth and phosphoric acid (top and bottom).

B.2.2. Influence of Temperature Levels on BPO Colour

The curves in fig.2 (a, b, c and d) illustrate the different contour lines that materialise the behaviour of the colour change when the applied temperatures are at their high level (+1) and low level (-1). When these temperatures are at their high level, the minimum values of the contour lines of the colour are around 14.4 and when there are at their low level, these lines oscillate around 15.4. These contour lines show that the colour varies according to the temperature levels applied. This could be explained by the fact that the high temperature level favours the evaporation of the additional water quantity and the decomposition of the carotenoids. Indeed, heat treatments can affect the integrity of carotenoids [16]. Moreover, the increase in temperature contribute to the reduction of the viscosity of the oil, thus ensuring better dispersion of the particles, and in the maximum fixation of the gums susceptible to be found in the palm oil [17, 18].

It is also apparent that the decrease in colour is influenced by the effect of opposite temperature levels: the low level of the first temperature and the high level of the second temperature are an illustration with a high colour around 15.0. Thus, the maximum introduction temperature of phosphoric acid is to be avoided because it contributes to its decomposition (roasting effect) and thus to reduce its effectiveness. However, the earth introduction temperature can range up to around 130°C because the American earth has moisture content slightly above the average and requires high temperatures for evaporation of the additional water quantity contained in palm oil. High temperatures during discolouration are not to be extended because of the risk of desorption and reversion of colour.



X_1: Introduction temperature of phosphoric acid (°C); X_3: Introduction temperature of decolourising earth (°C)

Fig. 2. Isoresponses curves of colour change as a function of different temperature levels

IV. Conclusion

The objective of this study was to optimise the use of decolourising earth and temperature in the discolouration of crude palm oil. Three different decolourising earths (American, Indian and Chinese) were characterised to use the best. The modelling of the process was carried out using a four-factor composite experimental design. The results indicate that the American earth is the most effective, followed by Indian and Chinese earths with discolouration 15.1, 15.7 and 16.7 red, respectively. The effect of the most effective American earth with DOBI 2.3 oil shows that when decolourising earth and phosphoric acid are at their high level, the minimum values of the contour lines of the colour are at 14.6 and when they are at their low level these lines oscillate around 15.2. The effect of temperature indicates that when the introduction temperatures of phosphoric acid and decolourising earth are at their high level the minimum values of the contour lines of the colour are around 14.4 and when they are at their low level these lines oscillate around 15.4.

The second order polynomial model, with satisfactory validation in terms of R^2 and AAMD, was generated and it described the discolouration process. The optimum discolouration conditions (≤ 20 red max) of the crude palm oil ($P \leq 0.05$) are: 100°C and 0.06% for the temperature and the percentage of phosphoric acid; 116°C and 1.2% for the temperature and the percentage of decolourising earth.

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